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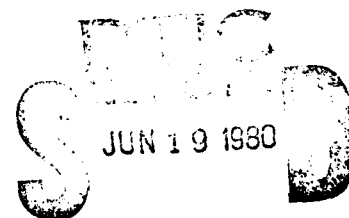
EFFECT OF SPATIAL AND TEMPORAL VIDEO IMAGE
COMPRESSION ON MILITARY TARGET DETECTION

by

Joseph E. Swistak

April 1980
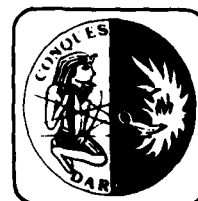
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    A study was conducted which examined the effects of simultaneous spatial and temporal bandwidth compression on observer detection and recognition performance of military targets. Five levels of temporal (frame rate) and four levels of spatial (bits per pixel) were co-varied using a factorially designed experiment. Of special interest was any interaction effect between the two main variables. A total of 48 observers were divided in 4 groups of 12. Each group was presented a single spatial reduction level at all five temporal reduction levels. Statistical analysis

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revealed no significant differences in subjects' detection or recognition performances due to changes in the temporal rate at which information was presented. Changes in the spatial levels (resolution) did have a significant effect on both detection and recognition performance. Although significant differences in subject performance were noted due to the interaction of the two main variables, in-depth analysis revealed the interaction effect to be anomalous. The single most critical element of bandwidth compression appears to be spatial.

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I. INTRODUCTION

In recent years there has been increasing interest in visual information processing. That interest has been brought about, in part, by advances in communication satellite technology, computer technology, military systems, and educational systems. Whether a given application is in national defense, general communications, or education, major system trade-offs must be evaluated at the interface between hardware/display and the user/observer. In general, the objective is to provide a level of display fidelity appropriate to the observer's capabilities and task requirements while considering the operational environment of the overall system (e.g., military combat versus civilian peacetime). In systems involving video images (television monitors), image compression and frame rate are two prominent variables from the standpoint of system cost-effectiveness and observer performance reliability. The digital compression of image information has at least two major benefits of widespread application — one in the military and the other in nonmilitary systems. The primary military advantage is that the associated Radio Frequency (RF) transmissions are less susceptible to deliberate interference (i.e., "jamming"). The nonmilitary benefit is that image compression allows more information to be transmitted faster, thus saving not only time but energy as well.

In terms of a simple analogy, image compression may be characterized as a scene or an object represented in a two-dimensional plane (e.g., as a photograph or a video display). An extremely fine grid is placed over the scene. To represent the scene, each square or cell of the grid is assigned a value on a scale with values corresponding to shades of contrast from low to high. The finer the grid, the greater the number of gradations on the light-to-dark scale and the higher the fidelity of the display. To transmit the information thus represented, the specific row and column designations and the light-dark values assigned to each cell would have to be sent. As the requirement for display fidelity increases, more time and energy is needed for transmission.

When a human observer uses the display to detect and classify objects (targets), the required level of fidelity depends upon several factors. Among these are the relative size and shape of the targets in the scene, the similiarity of the figures designated as targets to other objects (non-targets), and the level and distribution of intensity contrasts in the scene. The level of fidelity which includes the degree of visual detail and resolution needed is dependent on the observer's visual and perceptual capability to detect, recognize, and classify targets at specified levels of reliability.

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Given the grid format as discussed above, image compression is a technique of representing the scene with a lesser number of cells and light-dark gradations. The compression or transformation is accomplished by replacing groups of cells with a single cell representing the average value. The resulting grid is comprised of fewer cells or subdivisions, with the gradations across cells less gradual than before. Displays subjected to this type of image compression are seen as "blocky," as though the scene was depicted by the arrangement of tiny rectangles with a limited range of contrast. Where the target is a rectilinear form of uniform contrast (e.g., an office building) a moderate amount of image compression does not seriously degrade target visibility. Where the target is of irregular shape, especially with curved lines in its borders, a modest amount of image compression may render the target virtually unrecognizable. This is more likely where the target is small relative to the elements of the display grid.

To the foregoing considerations one may add the dimension of motion. This occurs whenever the camera (sensor system) or the target is in motion relative to the other. Whereas image fidelity of the grid representation is similar to having many tiny picture elements presented contiguously and simultaneously, representation of relative motion is analogous to creating and displaying many such grids, one after the other. A similar principle is that used by the common motion picture camera. If the series of grids (frames) is photographed rapidly at fixed intervals and played back at the same rate, the relative motion will be displayed with high fidelity. If the frames are not taken at a high enough rate (which depends on the rate of movement being photographed), the subject in the playback will appear to move in a stepwise fashion rather than continuously.

The frame rate needed is similar to the degree of fidelity required in each frame or grid representation. That is, the frame rate is dependent on the needed degree of reliability which is a function of the scene viewed and the targets to be detected and recognized. And, as with the fidelity of each frame, the more frames per unit time required, the more time and energy needed for their transmission.

Reducing the display fidelity may result in deterioration of the observer's performance. The degree of degradation depends on the target detection and recognition requirements placed on the human observer. Image compression and frame rate reduction represent a decrease in display fidelity. Furthermore, image compression used in conjunction with reduced frame rates may result in degradation of observer performance greater than the sum of the effects of each variable alone (i.e., an interaction effect of image compression and frame rate on target detection and recognition).

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a. **Purpose.** The present study was designed to investigate:

(1) The effect of image compression on target detection and recognition.

(2) The effect of frame rate on target detection and recognition.

(3) The effect of a possible image compression by frame rate interaction on target detection and recognition.

In this study, the terms "detection" and "recognition" refer to two successive levels of visual discrimination. "Detection" represents the first level of judgment by the observer — that an object in the scene is a member of the class of objects designated as targets. For example, the observer may report a "detection" on the basis of an object's outline, contrast, shadow pattern, and so on. The discrimination at that time may be simply between man-made and natural objects, or it may be to the level of a general category of man-made objects such as buildings, roads, or vehicles.

The second stage, "recognition," is when the observer specifies the detected target to a greater degree; i.e., having "detected" a target, he now "recognizes" it as a "jeep." By this definition, recognition presupposes detection.

b. **Experimental Context.** As a basic research issue there are many variables and interactions to be evaluated in image processing. Tests performed with simplified extractions of the independent variable (e.g., geometric shapes, patterns, etc.) would be useful in identifying the effects on the dependent variables (target detection and recognition). As an issue of applied research, however, it is possible to evaluate directly the influence of the display parameters on observer performance. And, taking the applied approach, the results would be more relevant to the operational system evaluated with the data also providing insight into the basic display-observer interface. The latter approach was taken in the present study. In this investigation, observers viewed video monitors that show prerecorded scenes of aerial reconnaissance flights. The task of the observers was to search the scene for the presence (detection) of a vehicle and then to identify (recognition) the vehicle by type (i.e., military jeep or truck of a given size). The operational system associated with this task is described below.

c. **Remotely Piloted Vehicle (RPV) System.** The function of the remotely piloted vehicle (RPV) system is to obtain information by means of aerial reconnaissance. In the RPV system, the airborne vehicle carries a video camera that flies a pre-established computer-controlled course. From the aircraft, two types of information are transmitted back to its base and received by two persons, with each person having

a different function. One type of information is that which permits the course and location of the aircraft to be monitored while in flight. This monitoring is done by the first of the two persons mentioned. The monitor or "controller," as is the common designation, does not fly the aircraft by remote control in a continuous mode. Rather, the flight path program is updated periodically by use of a standard keyboard input to the computer. The controller's display is a standard Cathode Ray Tube (CRT) radar-type display upon which the remotely piloted vehicle is represented by a moving point of light. (The controller does not see the output of the airborne video camera.) A direct video scene of the ground forward of the aircraft is monitored by the second person, designated as the "observer." The observer searches the scene for prescribed targets. When a target is detected or suspected to be present, its apparent location is communicated to the controller. The controller updates the computer-controlled flight path to put the aircraft on course to the suspected location of the target, thus providing the observer with an improved view of the area in question.

A typical RPV system is designed to transmit analog information back to its base through a wide-band RF signal. Such signals, however, may be disrupted readily ("jammed") by electronic countermeasures. When this happens, not only is the video reconnaissance information lost but control of the vehicle is jeopardized as well. This susceptibility to jamming can be alleviated by reducing the bandwidth of the RF signal. To do so, however, requires alteration of the temporal or spatial characteristics of the video information or both, depending on the reduction process used.

The temporal characteristic of the information is essentially synonymous with frame rate as described earlier. The procedure is to convert the video information from analog (primary image rate is 30 frames per second) to digital form prior to transmission. Once converted, the total set of frames (a second, minute, hour, or any desired unit of time) may be sampled and just the sample transmitted. By selecting and transmitting every other frame, for example, the view would be temporarily reduced or "compressed" by 50 percent. Correspondingly, to provide the video observer with a continuous display, each frame would be presented for twice its normal duration. For the aerial reconnaissance scenes used in the present study, a reduction from 30 frames per second (analog rate) to 20 frames per second does not markedly disrupt the apparent smoothness of the view over time. At 10 frames per second the display is described subjectively by observers as "slightly choppy." At lower frame rates there is an obvious stepwise change in the scene from one frame to the next. The effect of such reductions in frame rate on the observer's ability to detect and recognize military targets was one of the main interests of this investigation.

In addition to altering the temporal characteristic of the video information to be transmitted, it is possible, as discussed earlier, to vary or "compress" its spatial characteristic as well. The technique is a complex averaging process applied to the many elements comprising the video scene. These elements are dots and lines which vary in contrast to represent the visual scene and which may be specified quantitatively as "bits of information." In the process of compression, the number of bits is reduced by replacing details with an average value.

The effect on the video scene by increasing levels of spatial compression is illustrated in Figure 1. The views shown are: (a) analog (no compression), (b) reduction to 8 bits per picture element ("pixel"), (c) reduction to 2 bits per picture element, and (d) reduction to 0.5 bit per picture element. In the scene shown, the target is a 2½-ton truck located slightly below the center of the picture. As may be seen, as compression is increased (bits per pixel are reduced), visual details and gradations of shading are decreased and the image assumes an appearance typically described as "blocky," owing to the black, white, and gray squares that comprise it.

A question of major interest addressed by the present investigation was the extent to which image compression effects observer detection and recognition of military targets (vehicles). Previous studies[1] [2] have examined the effect in target detection/recognition due to image compression, but none has evaluated the possible interaction effects of simultaneous reduction in temporal and spatial information: i.e., *reduction in frame rate and bits per pixel.* The present study was designed to address that issue.

II. METHOD

The video tapes used in this study were taken from a set of actual flight test recordings of an RPV system. The tapes were reprocessed to provide the desired frame rate and image compression levels.

a. **Selection and Processing of Video Reconnaissance Tapes.** During a preliminary field evaluation of the RPV system at Fort Huachuca, Arizona, approximately 250 video tapes of aerial reconnaissance trials were produced. Each tape contained 10 "runs," with a run comprised of a single, straight and level flight segment oriented so as to fly directly toward and over a specified target on the ground. The video camera was carried by a Cessna Super Skymaster aircraft equipped with a short-takeoff and -landing system (STOL). All runs were made at a constant altitude of

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[1] M. L. Hershberger and R. J. Vandervalk, *Video Image Bandwidth Reduction/Compression Studies for Remotely Piloted Vehicles.* Tech Rpt. ASD-76, Hughes Aircraft Company, Culver City, CA (October 1976).

[2] H. C. Self and S. A. Heckart, *TV Target Acquisition at Various Frame Rates.* Tech Rpt. AMRL TR-73-111, Aerospace Medical Research Laboratory, Wright-Patterson AFB, Ohio (September 1973).

Figure 1. Sample of the effect on the video scene due to increasing the levels of spatial compression: (a) no compression; (b) 8 bits per pixel; (c) 2 bits per pixel; (d) 0.5 bit per pixel.

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1,500 feet with the camera looking forward and downward with respect to the aircraft's trajectory. Each run was photographed twice: once with a narrow (6.5°) field-of-view lens and once with a wide-angle (16°) lens. All runs were made at the same altitude, heading, and ground speed. All runs were over the same section of terrain. The only conditions to vary from one run to the next were the type and location of target and the field-of-view (6.5° versus 16°). All of the original tapes were analog recordings.

     b.   Visual Background. The ease or difficulty with which visual targets can be detected depends in part upon the background against which they appear. The present target surround consisted of light colored sand populated by clusters of scrub pine and other indigenous flora. The effect was a mottled background (see Figure 1) that provided substantial visual noise or competition in searching for targets.

     All 250 tapes were reviewed for possible use in the present study, and a set of runs was selected which represented the following basic conditions: (a) four types of target vehicle (jeep; 5/4-ton truck; 2½-ton truck; armored personnel carrier (APC)); (b) reconnaissance runs (tape) for each target (varying location) photographed variously with wide and narrow fields-of-view. This basic material was all in analog format. On each run there was one, and only one, target.

     From the foregoing tapes a master analog copy and a series of modified tapes were prepared. The modification was a conversion and image compression process which produces the variations in spatial (bits per pixel) and frame rate necessary to conduct the study.

     The spatial compression was done by the Northrop Corporation using an HAAR transformation.[3] Once transformed, the tape frames were sampled systematically and reproduced at the Night Vision and Electro-Optics Laboratory to give the total set of experimental conditions (i.e., tapes with the required combination of spatial compression and frame rate). There were four targets in all, each represented in the different spatial temporal conditions. Each tape contained the same 10 target runs with the order of runs randomized across tapes.

     c.   Experimental Design. A split-plot design was used with subjects nested within levels of spatial compression (bits per pixel). Subjects were randomly assigned to their respective groups. Within a given level of image compression each subject observed all remaining combinations of frame rates, targets, and fields-of-view (wide versus narrow). The spatial compressions were: 0.5, 2, and 8 bits per picture element

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[3] T. Leibhoff, H. Henning, T. Noda, and B. Deal, *Final Report for Experimental Development of a FLIR Sensor Processor.* Technical Report 77Y106, Northrop Corporation, Anaheim, CA (September 1977).

as well as analog. The frame rates were 1, 3, 6, 10, and 30 frames per second. A detailed discussion of this experimental design may be found in Kirk.[4]

d. **Subjects.** Subjects were 48 paid volunteers ranging in age from 17 to 38 years, with a mean age of 28 years. None had prior experience with an RPV system or with military target detection in general. All subjects were examined by an optometrist prior to the study to ensure that no visual anomalies existed that would adversely affect the study. All subjects had visual acuity of at least 20/30, uncorrected or, if necessary, with glasses.

e. **Apparatus.** The equipment was arranged so that four observers could be tested simultaneously. Each observer performed in a cubicle that was visually isolated from the other three observers and from the experimenter.

An observer station consisted of a 15-inch, black-and-white video monitor (Ball Miratel Model BH-15) on which the observer viewed the aerial reconnaissance scene and searched for the target. The observer responded by means of a set of six switches mounted on a single control box. The functions of the switches were as follows: Number 1 was used to report "target detection;" Numbers 2 through 5 were used to report recognition of the jeep, 5/4-ton truck, 2½-ton truck, and armored personnel carrier, respectively. Number 6 switch was designated as a "reset" and was used by the observer to cancel any responses made within a trial as, for example, to cancel an incorrect "target detected" response when, upon closer inspection of the scene by the observer that response proved to be in error.

The video tapes were played on a Sony tape deck, Model TC-2000. The signal was fed to the four subject monitors through a Panasonic distribution amplifier (Model WJ-300). Contrast levels of the four monitors were equalized within the limits of their available range and with reference to a Spectra-Pritchard Model 1980 photometer.

Presentation of the taped material and recording of observers' responses was accomplished by a Hewlett-Packard calculator (Model 9825A). To start a trial (tape presentation), the experimenter pressed a button on the calculator. During the trial observer responses were recorded separately (contingent upon the "reset" function as described above). At the end of each trial, upon command of the experimenter, the data were transferred to a magnetic disc (Hewlett-Packard Model 9885M).

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[4] R. E. Kirk, *Experimental Design: Procedures for the Behavioral Sciences.* Wadsworth, Belmont, CA. (1968).

f. **Procedure.** Subjects were assigned at random to experimental groups. The first part of the day was devoted to orientation and practice. Formal data collection then followed, with all tests on any observer being completed with a single day.

g. **Orientation and Practice.** Observers were tested in groups of four. Prior to conducting the formal data collection trials, the observers were told the purpose of the research and what their task would be. They were shown three-dimensional scale models of the targets that they would be searching for and they were shown three sample runs (not included in the formal data trials) on the monitor. Finally, each observer was given 30 practice trials (analog tape only; no image compression or frame rate reduction) during which the experimenter verified that everyone understood the task and the correct use of the response switches. At the end of each training trial the experimenter pointed out and identified the target. In the training trials and in later test trials there was always one, and only one, target present. The instructional and practice sessions lasted approximately 2½ hours.

h. **Data Collection.** Each observer viewed a total of five runs distributed in equal numbers on five separate video tapes. As noted previously, there was a different set of tapes for each (nested) group of observers. Each tape ran continuously for 35 minutes. Observers were permitted a 10-minute rest period after each of the tapes. A 1-hour lunch break was given at the conclusion of the first test tape. The second through the fifth were run after the lunch period.

For each group of observers, the first tape presented was always at a rate of 30 frames per second. The order of the remaining tapes, representing the remaining frame rates, was randomized. For each data trial (run), an observer had an opportunity to make a detection response and a recognition response by pressing the corresponding switches on his panel. If an observer pressed his reset switch at any time during a trial, any responses made previously during that trial were automatically deleted. A trial was considered valid and data were recorded only if a target was recognized correctly.

If an observer reported "detection" but no subsequent "recognition," or if the subsequent recognition was in error, the trial was treated as if the observer had made no response. On each trial, however, the target in the video scene was always approached close enough to insure ultimate recognition of the target. Whether or not recognition was simultaneous with detection from the observer's standpoint, the observer was required to report a detection before reporting the target name (jeep, APC, etc.). Observer responses were recorded as elapsed time commencing with the start of each trial. Given the measure of elapsed time plus the speed and altitude of the photographic aircraft, it was possible to calculate the respective detection and recognition ranges.

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III. RESULTS

Observer responses were recorded as the time elapsing between the start of a test run and the report of target detection (and, subsequently, target recognition). Since the length of the original flight segment of the camera-carrying aircraft was known, along with the aircraft speed and altitude, it was possible to convert each elapsed time measure into the range to target at the point of detection (or recognition).

a. **Summary.** The data concerning target detection were of primary importance. Since each detection response was followed by a correct recognition of the target (always at a closer range, since a detection report had to be made before a recognition report would be accepted), the detection data reported here represent 100-percent accuracy of subsequent target recognition. Results are presented primarily for the detection measures since the recognition data added little more of consequence.

In brief, the wide-angle-view data were associated with such short target detection ranges as to be of no further use in this study from a military operational standpoint. Consequently, after initial inspection of the data, that variable was dropped from the analysis.

In general, a shorter average detection range was associated with the smaller target (jeep); targets (size) did interact with the spatial compression variable.

Image spatial reduction was associated with a reduction in mean target detection range. The variable of frame rate reduction, however, had no noticeable effect on target detection range, nor did this variable interact with the image spatial compression variable.

b. **Angle of View.** The variable of camera viewing angle was included in the study primarily as an operational issue. Observer performance with respect to field-of-view was found to be significantly poorer with the wide-angle view than with the narrow field-of-view. Figure 2 presents mean detection range and mean recognition range for each field-of-view. The mean detection range for the narrow view (6.5°) was 1991 meters compared to 1052 meters for the wide view (16°). The mean *recognition* range was 625 meters for the narrow view and 146 meters for the wide view. As may be seen in the figure, targets were detected at roughly twice the distance under the narrow field-of-view condition than with the wide field-of-view. Moreover, the mean recognition range with the narrow field-of-view was more than four times greater than with the wide field. On the basis of the poor performance with the wide field-of-view, the data for that condition were excluded from further consideration in the study. The remaining results and discussion, therefore, are restricted to data obtained under the narrow field-of-view condition.
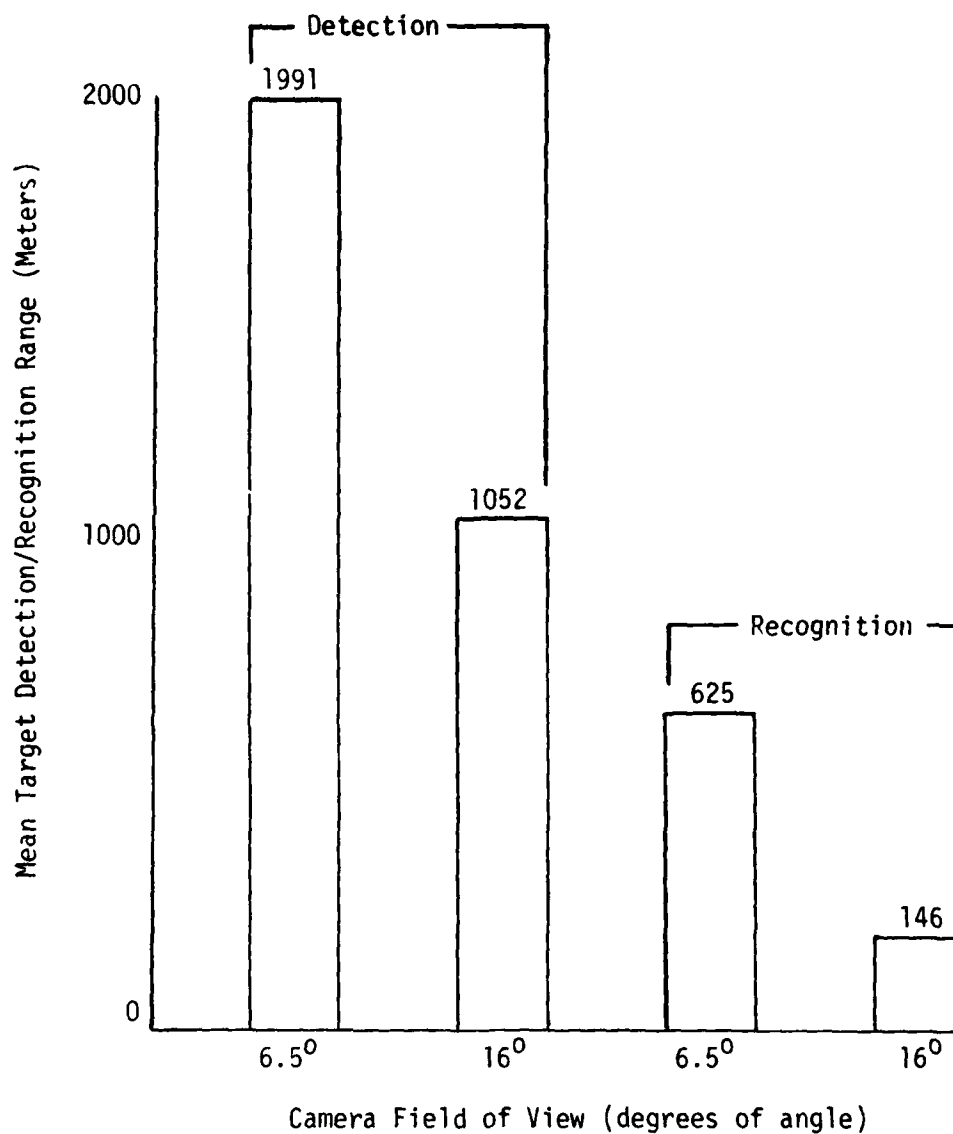
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Figure 2. Mean range of target detection and target recognition for narrow (6.5°) and wide (16°) field-of-view of the video recording camera.

c.   **Type of Target.** The targets were comprised of four types of military vehicles.   In order of increasing size, they were: jeep, 5/4-ton truck, 2½-ton truck, and armored personnel carrier (APC).

Figure 3 presents the mean detection range for the respective target vehicles.   The mean detection ranges in meters were as follows: jeep, 1359; 5/4-ton truck, 2281; 2½-ton truck; 2214, and APC, 2609.   As might be expected, the jeep, which was the smallest of the four targets, was associated with the shortest detection range.   The armored personnel carrier, the largest of the four vehicles, was detected at the greatest range.   On the average, the APC was detected at twice the distance of the jeep.   The longer detection range for the APC, however, was found to be due in part to a characteristic unique to that target in the video tapes used.   Sunlight reflecting from the APC fording board and/or headlights produced a conspicuous glint pattern which artifactually enhanced the detectability of the vehicle in the context of the present study.   Thus, while the APC served the study as an alternative target and thereby contributed to the realism of the search task, the detection range data associated with it were considered not to be compatible with that obtained for the other targets.

d.   **Spatial Compression.** A question of major interest in this study was the overall effect of image spatial compression and whether the effect of such compression would interact with a further reduction in image fidelity associated with reduced frame rates.

Figure 4 presents the overall mean detection range for each level of spatial compression.   The means are based on all 4 target vehicles and all 48 observers.   Data are for the narrow (6.5°) field-of-view only.   The mean target detections were: 1340 meters for 0.5 bit; 1880 meters for 2 bits; 2380 meters for 8 bits; and 2375 meters for analog conditions.   As may be seen in the figure, a reduction of image information from analog to 8 bits per picture element resulted in no difference in mean target detection range.   When the image was compressed from 8 bits to 2 bits, the mean detection range fell by a factor of 20 percent, from 2375 meters to 1880 meters.   At 0.5-bit-per-picture element, the mean detection range was 1340 meters, representing a 44-percent loss in range over the 8-bit and analog conditions, respectively.
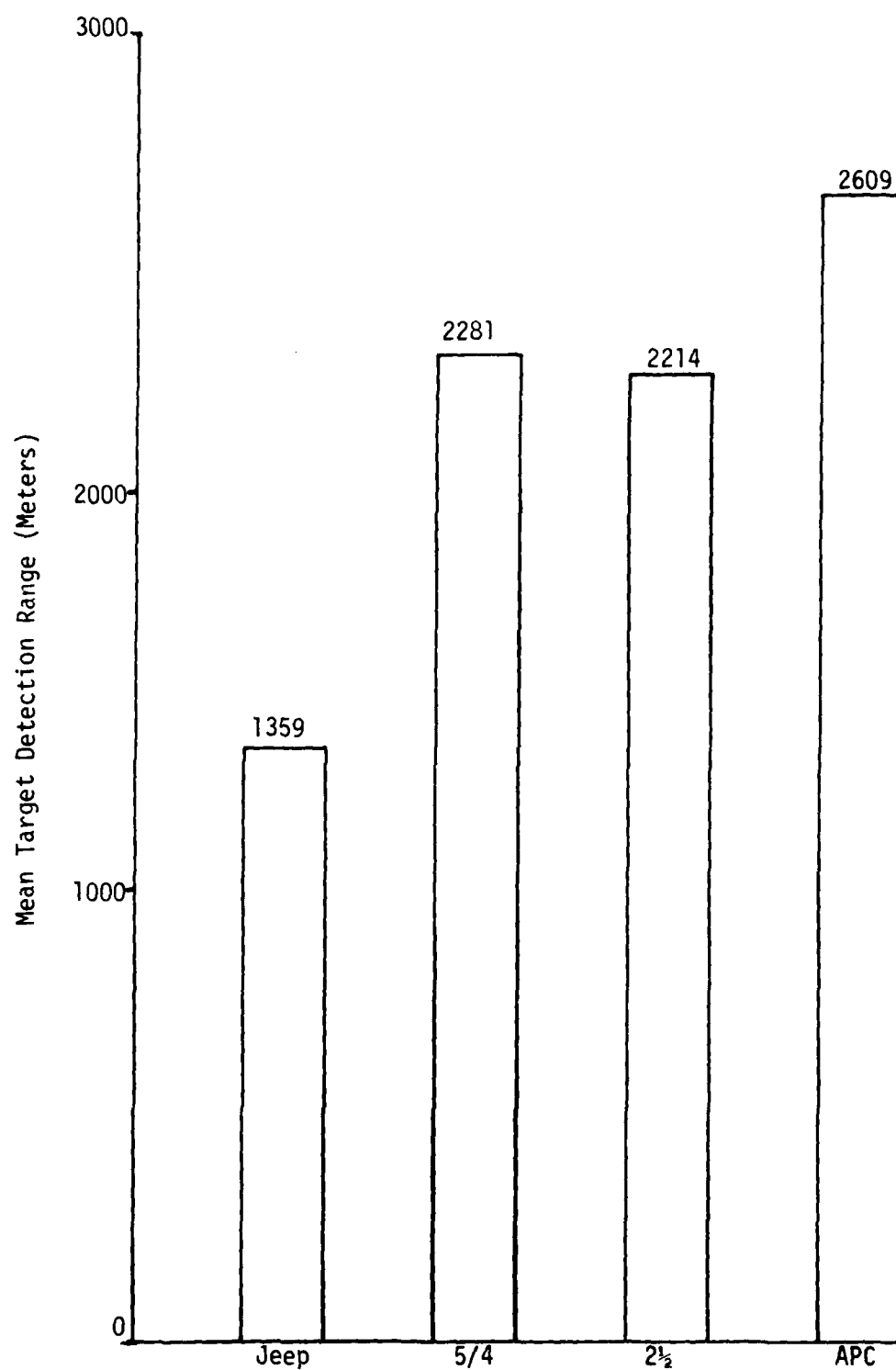
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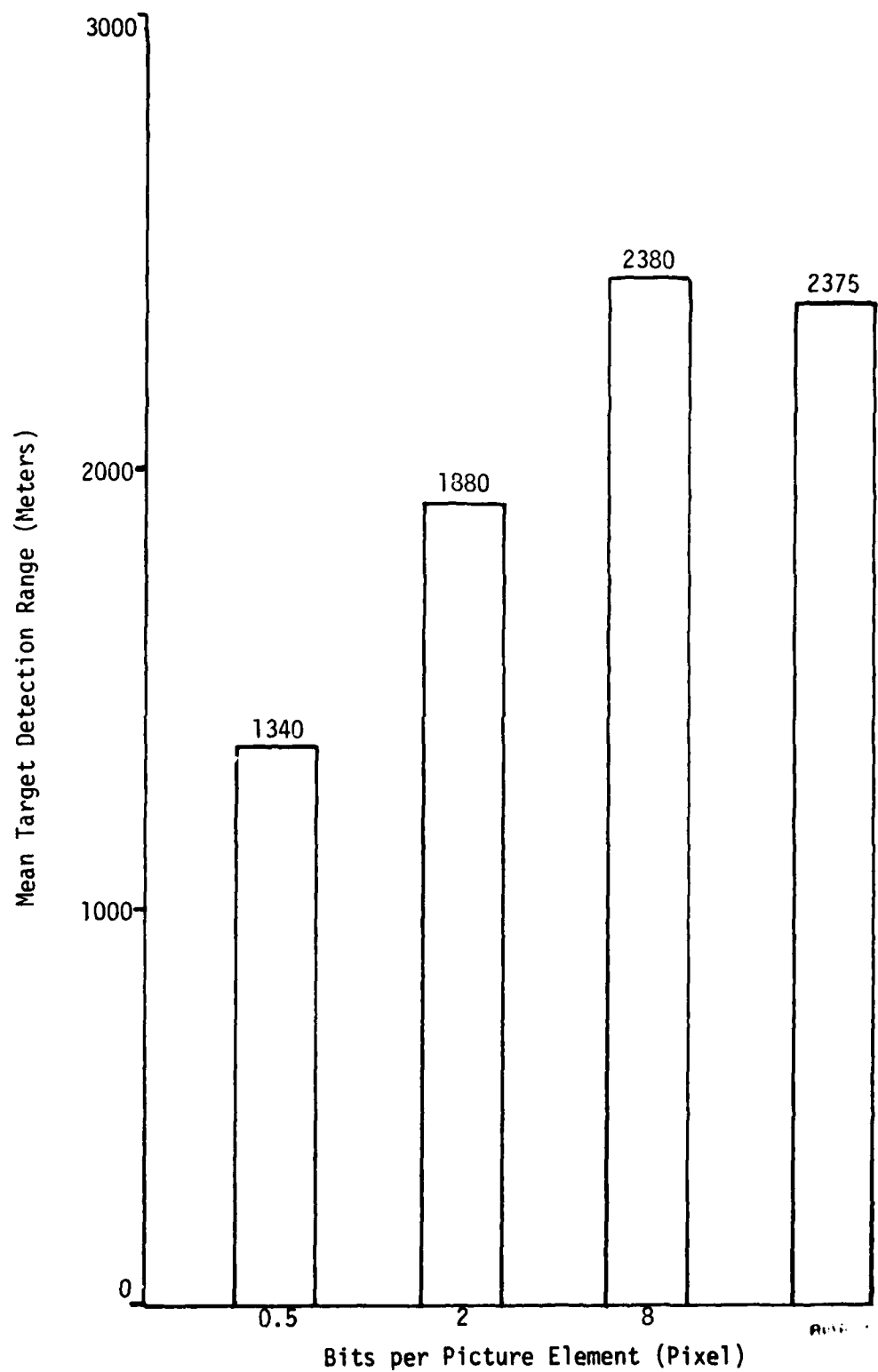Figure 3. Mean range at which various target vehicles were detected.

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Figure 4. Mean target detection range as a function of image spatial compression.

e. **Frame Rate.** The effect of image temporal compression (i.e., reduced frame rate) on target detection range was evaluated at five levels; these were 1, 3, 6, 10, and 30 frames per second (FPS). The mean detection ranges in meters were: 1945 for 1 FPS; 2030 for 3 FPS; 2018 for 6 FPS; 1920 for 10 FPS; and 2060 for 30 FPS. The overall means are presented in Figure 5. As may be seen in the figure, there was no appreciable difference in mean target detection range as a function of frame rate. The range of the means was from 2060 meters for 30 frames per second to 1920 meters for 10 frames per second. The slowest frame rate, one frame per second, was associated with a mean target detection range of 1945 meters.

f. **Image Spatial Compression and Frame Rate.** Figure 6 presents mean target detection range as a function of image spatial compression (bits per picture element) for each frame rate used in the study. Intervals of spatial reduction are based on powers of 2. That is, each successive level of reduction would contain half of the bits per picture elements of the preceding level. Therefore, the abcissa of Figure 6 presents $\log_2$ bits per picture element. The actual number of bits is shown in parenthesis beneath its respective $\log_2$ value.

The overall interaction effect was not statistically significant. In essence, the mean target detection range found was proportional to $\log_2$ bits per picture element over the range of 0.5 to 8 bits ($\log_2$ = -1 to 3). There was no significant difference in mean target detection range between 8 bits per picture element and analog ($\log_2$ 3 and 5, respectively). Moreover, this relationship was independent of frame rate.

g. **Target Vehicles and Spatial Compression.** It was of interest to compare the results obtained with the smallest target (jeep) with those of a large target (2½-ton truck) to see whether there was any effect due to target size or any target size interaction effects. Figure 7 presents mean target detection range as a function of ($\log_2$) bits per picture element for the truck and the jeep.

As may be seen in the figure, mean target detection range decreases approximately linearly when plotted against $\log_2$ bits per picture element. The loss in detection range, however, was proportionately greater for the jeep at the lower levels of bits per picture element. That is, in comparing observer performance of analog video vs 0.5 bit per picture element, the mean range for detection of the truck was reduced (degraded) by 36 percent as compared to 56 percent loss for the jeep. Thus, for these two targets the interaction of target type with spatial compression was statistically significant.
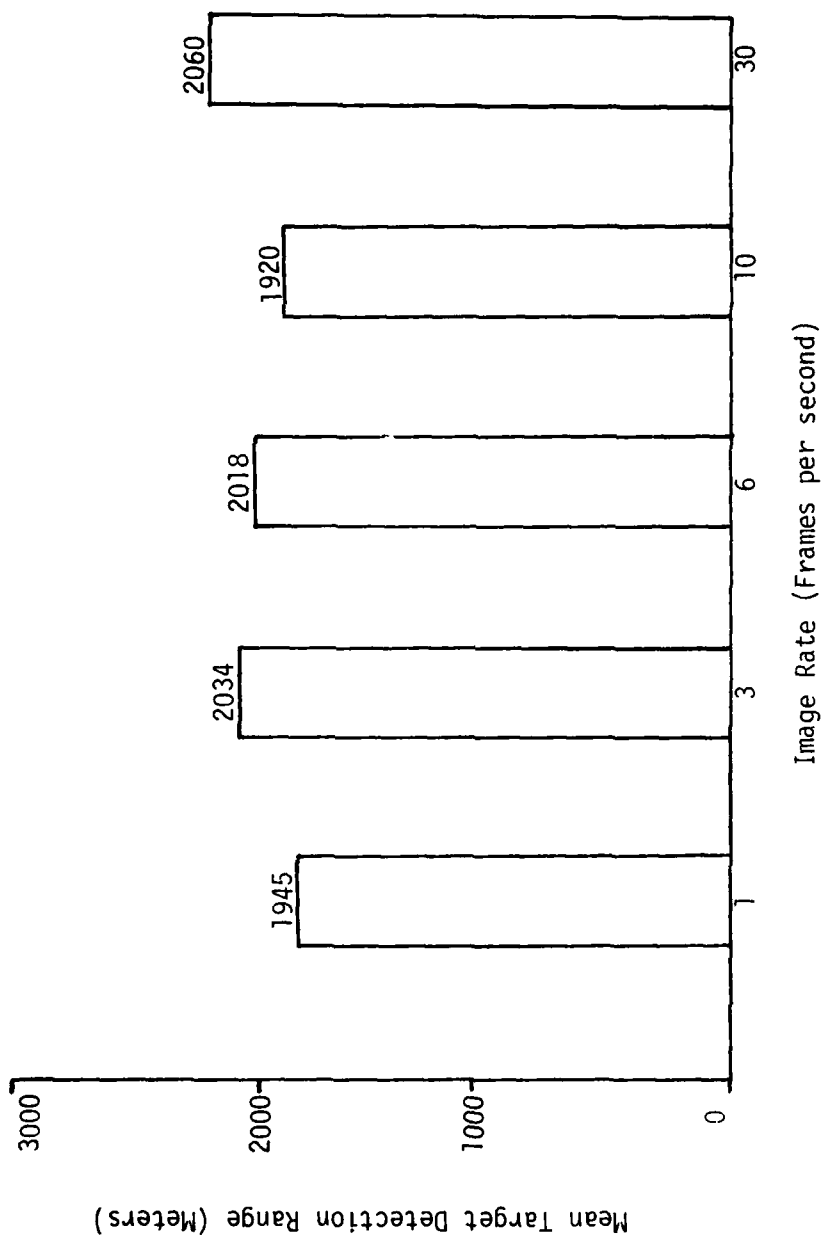
Figure 5. Mean target detection range as a function of image rate (frames per second).
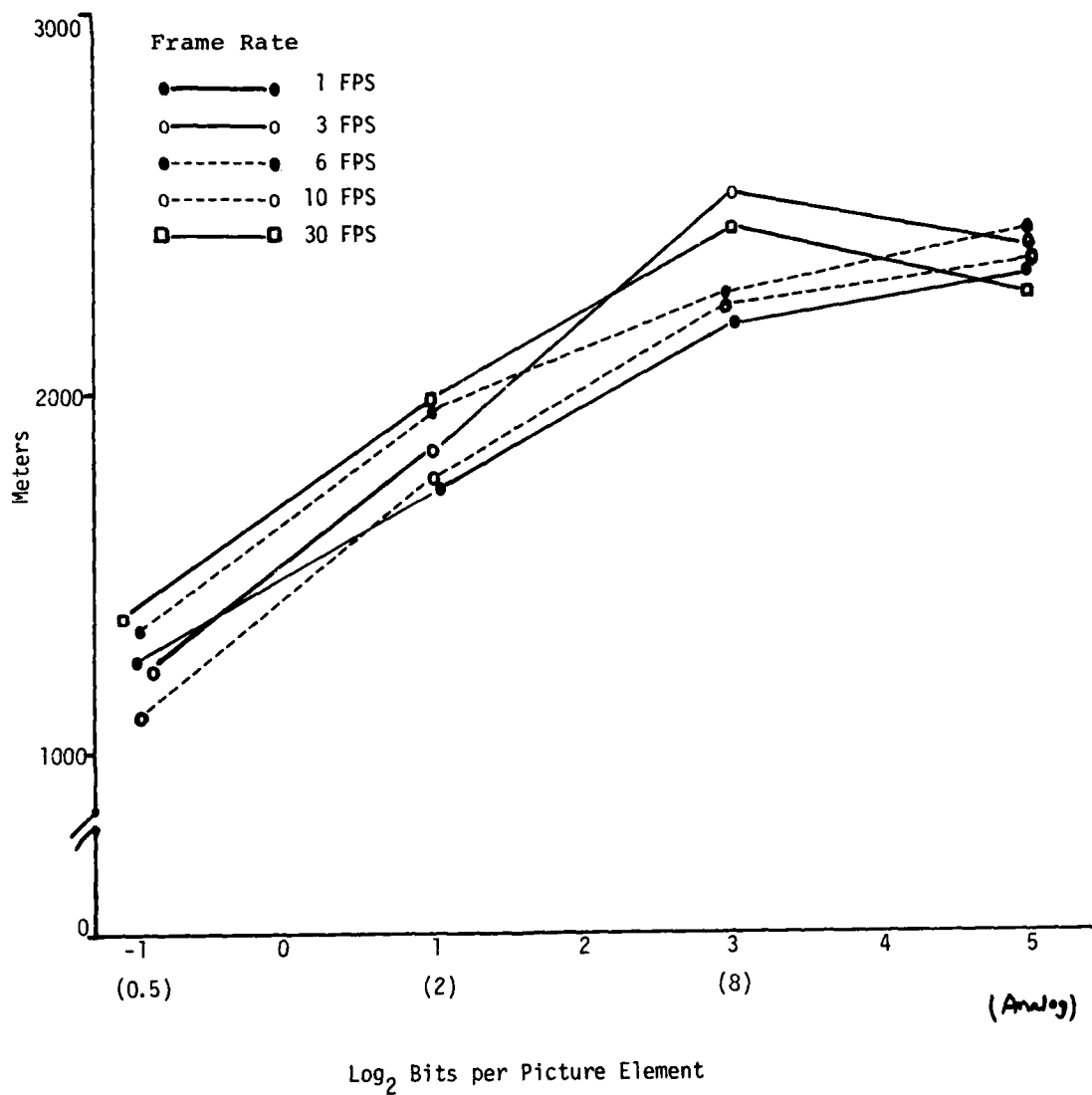
Figure 6. Mean target detection as a function of image spatial compression at each of five frame rates. Actual bits per picture element are shown in parentheses.

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3000

Mean target detection range (meters)

2½ ton truck

2000

Jeep

1000

0

-1   0   1   2   3   4   5
(0.5)   (2)   (8)

(Analog)
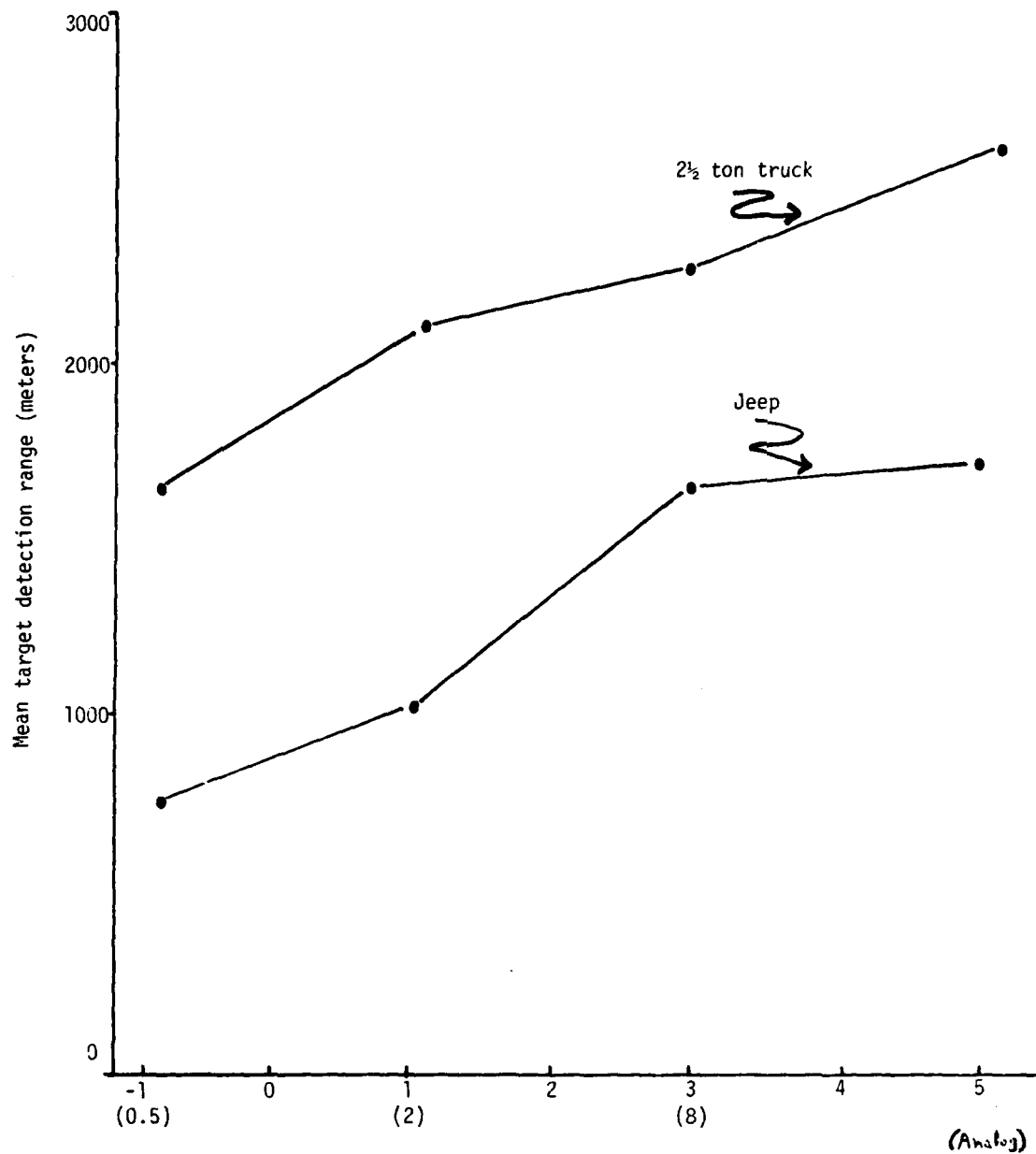
Figure 7. Mean target detection as a function of image spatial compression for 2½-ton truck and jeep.

IV. DISCUSSION

The effects of image spatial compression, temporal compression, and the interaction of these two variables in relation to visual target detection was the main interest of this study. A variety of targets were used which varied principally in size. Initially, the study design included video tapes taken with either of two fields-of-view ($6.5°$ and $16°$).

Observer target detection performance with the wider angle lens was so poor as to be beyond the range of consideration in the remotely piloted vehicle system. All data of any consequence, therefore, were based on the narrow field-of-view condition and have been reported accordingly.

No significant interaction was found between spatial compression and frame rate (temporal compression) nor did frame rate by itself have any effect on observer performance. Mean target detection range, however, did decrease essentially as $\log_2$ of spatial compression, and this effect was more pronounced for the smaller (jeep) target than for the larger (2½-ton truck) target. It is worthy of note, moreover, that a reduction in bits per picture element from analog to 8 produced no loss in mean detection range.

Reduction in detection range due to spatial compression may be explained in that the primary visual cues associated with these military target vehicles appeared to be contrast in shadow pattern and, possibly, shape. On the analog (uncompressed) tapes, the vehicles had a more geometric or angular appearance than did the competing elements of the background comprised mainly of shrubbery and trees. As the level of spatial compression was increased (bits per picture elements were reduced), the targets and the surrounding shrubbery became visually similar, hence the observers did not report detection until they had a closer view of the scene.

As for the absence of the effect on observer performance due to frame rate reduction, the result is not surprising when one considers that the targets were stationary. Even though the video camera was moving when the tapes were made, no relative velocity information was contributed by the targets. Therefore, to show an observer (for example) six frames in 1 second, each for a duration of 1/6 second, or to show him three frames each at a duration of 2/6 second would have little bearing on detection range. In fact, the slower frame rates (e.g., 3 per second or 1 per second), provide a more stable view in which to study and compare contrast patterns on the screen. In selecting an optimal frame rate, however, consideration should be given to the observer's subjective feelings of comfort (or fatigue) under prolonged viewing. This matter was not formally evaluated in the present study, but there were complaints from the

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observers that the three-frames-per-second condition was annoying and uncomfortable. Use of lower frame rates, such as one frame per 2 seconds, for example, would have to consider the speed of the camera vehicle and, correspondingly, the detection range forfeited in viewing a single frame for 2 seconds or more, before an update is provided. That question might be better addressed by measuring time to detect a target on a given frame taken at a given range. This would give the probability of target detection at a given range and frame rate when in the dynamic presentation mode.

V. CONCLUSIONS

In conclusion, the results of this investigation suggested that for stationary military targets viewed by means of a remotely piloted vehicle, a reduction in frame rate from 30 to 1 frame per second, does not adversely affect target detection range; spatial compression is not dependent upon the accompanying rate of frame presentation. Finally, smaller targets are detected, on the average, at a shorter range than are larger targets, and this difference is greater at higher levels of image spatial compression.

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